Calorimeter Simulations

Outline : Setup • Verification • Performance • Summary

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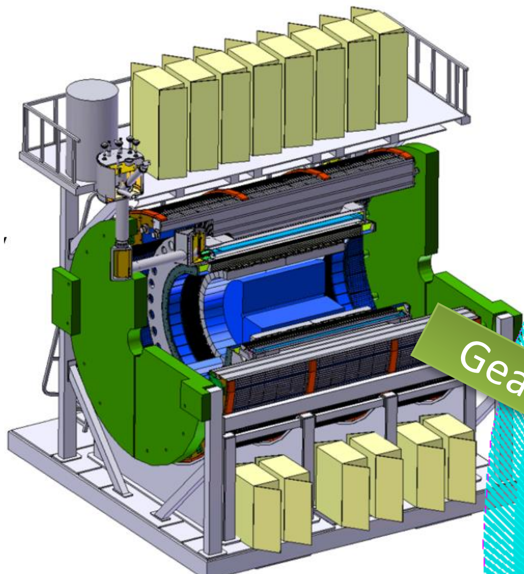
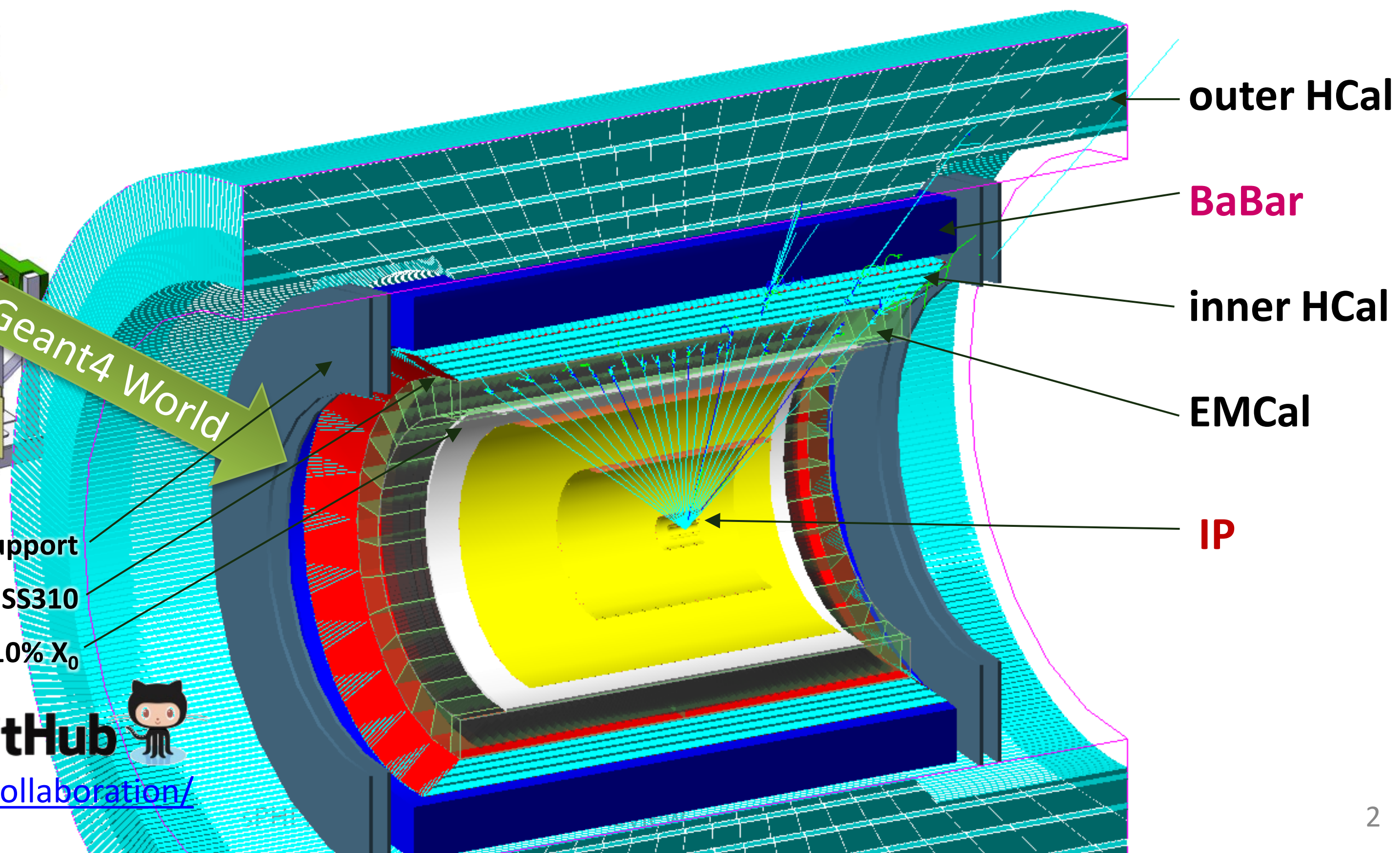
sPHENIX Calorimeters in Geant4

• EM calorimeter	(EMCal) :	18 X_0	SPACAL
• Inner hadron calorimeter	(inner HCal) :	1 λ_0	SS-Scint. sampling
• BaBar coil and cryostat.	(BaBar):	1.4 X_0	Coil & Cryostat
• Outer hadron calorimeter	(outer HCal) :	4 λ_0	SS-Scint. sampling

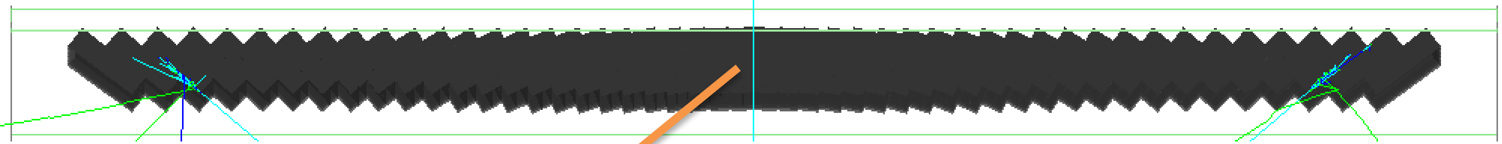




Open source @ GitHub

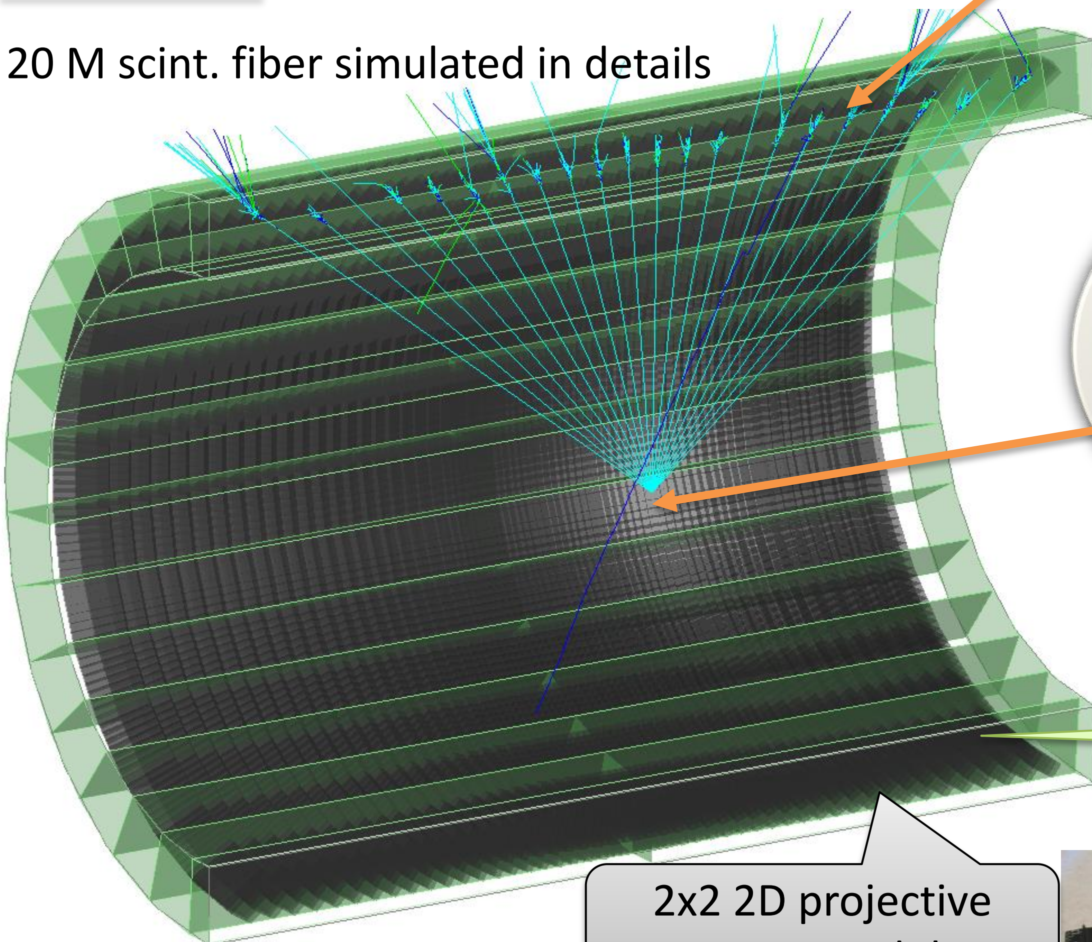
https://github.com/sPHENIX-Collaboration/

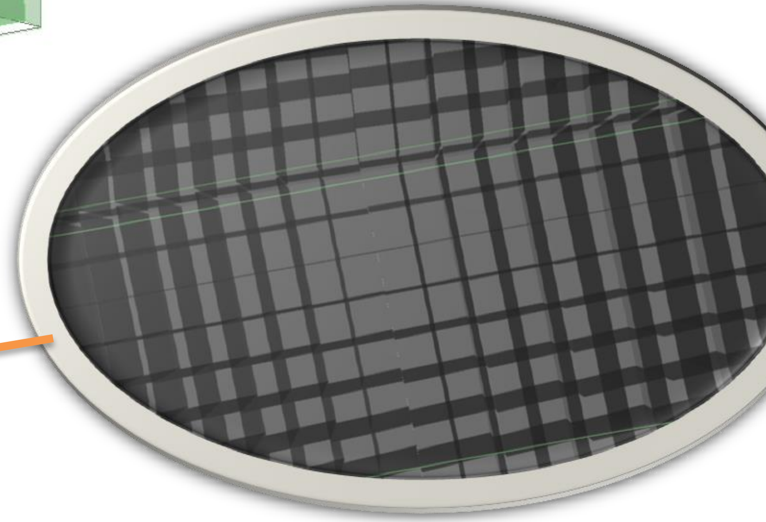
EMCal



20 M scint. fiber simulated in details

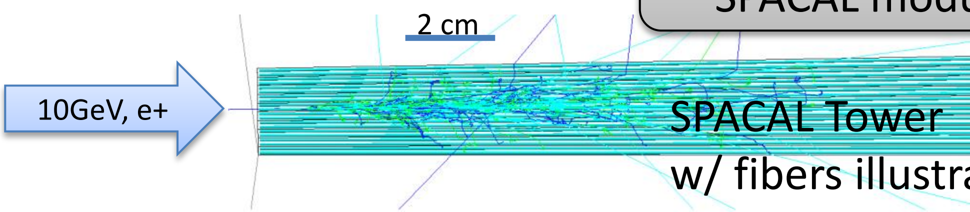
Towers project towards IP





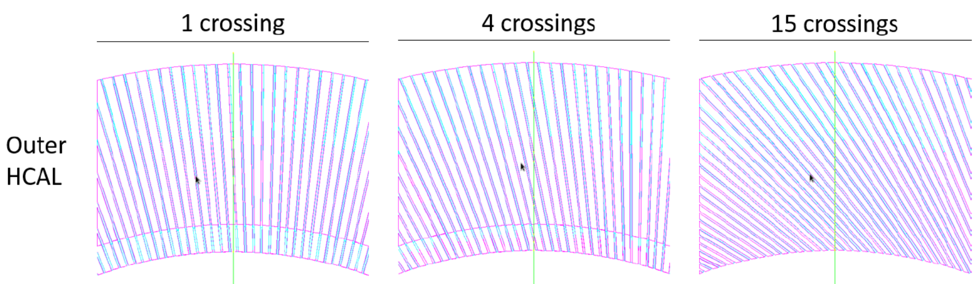
Stainless steel SS310 Support box

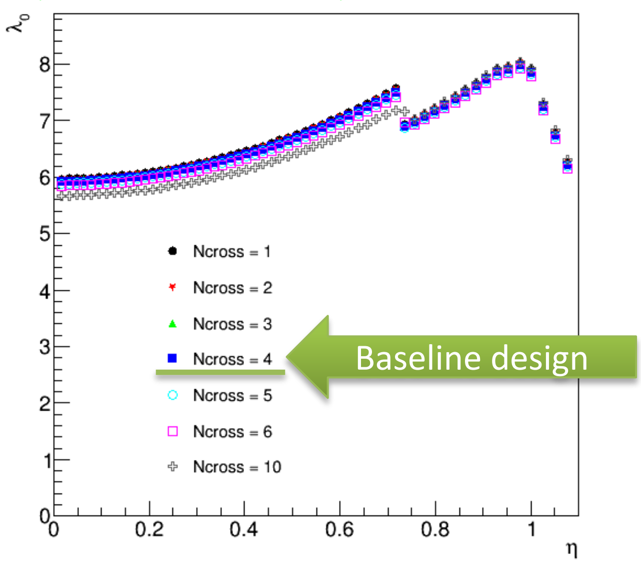
2x2 2D projective SPACAL modules

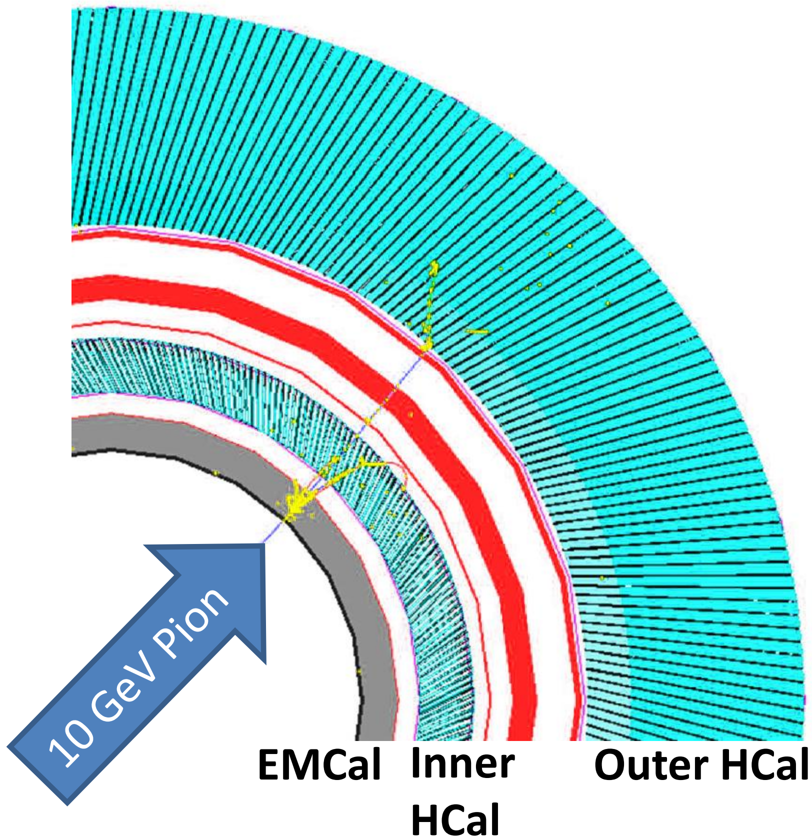


Simulation setup: HCal

- Setup
  - Tilted iron plate with scintillator inserted
  - Detailed magnet field map in detector
  - Variable tilt angle to optimize detector design
- Analysis: Geant4 hit → Scintillation light model → Tower readout → Digitization → Calibrated tower energy → Clustering/Track matching/Forming Jets





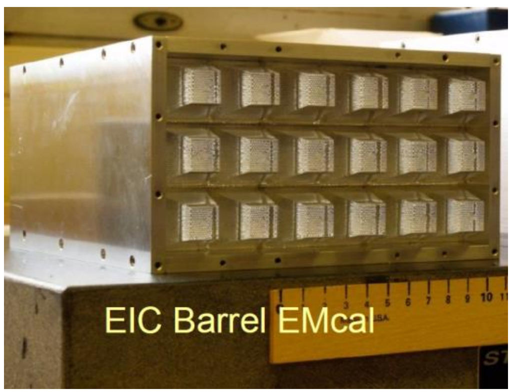


Verification of Simulation: EMCal

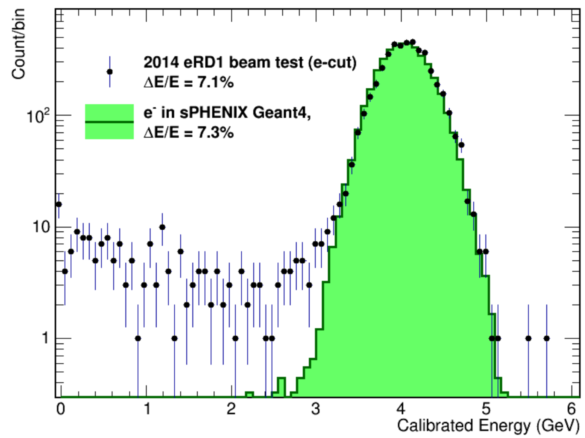
Verification of EMCal simulation using eRD1 2014 data VS sim using sPHENIX Geant4

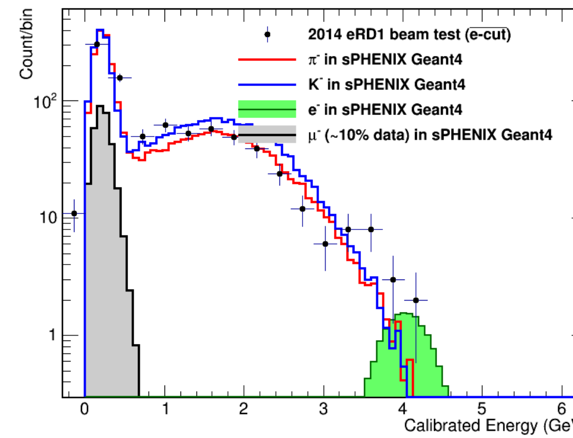
eRD1 2014 test beam

- 1D projective tower in 3x6 block
- slightly different fiber with double cladding

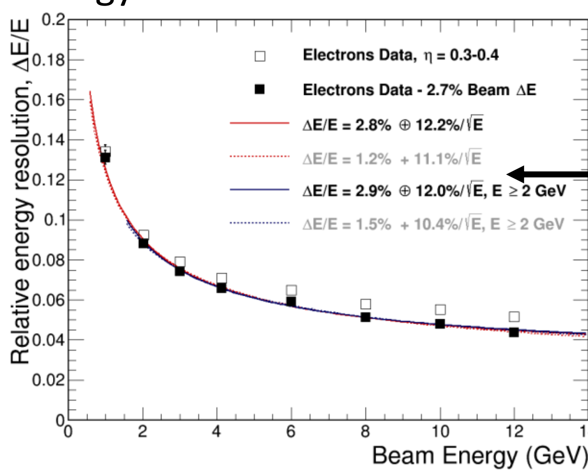


Beam test data reproduced in simulation (4GeV shown, more in pre-CDR)

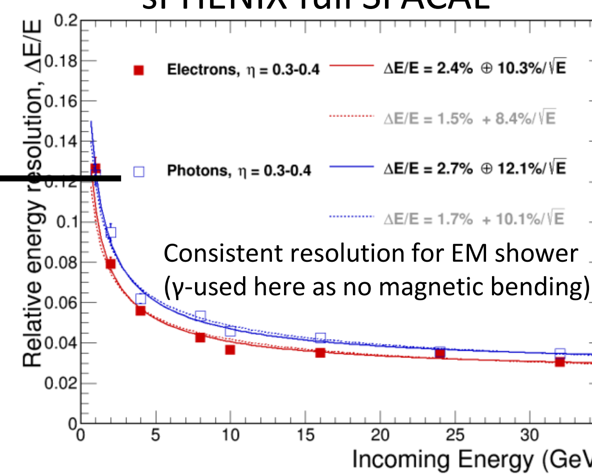




Energy resolution: eRD1 test beam

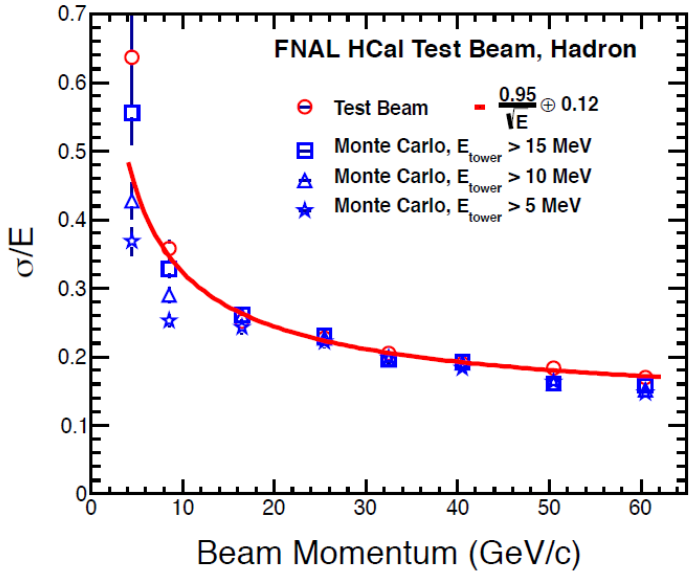


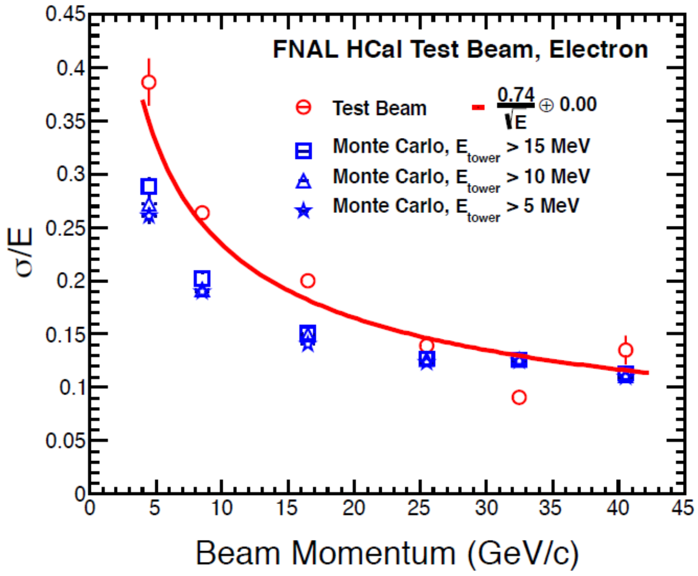
sPHENIX full SPACAL



Verification of Simulation: HCal

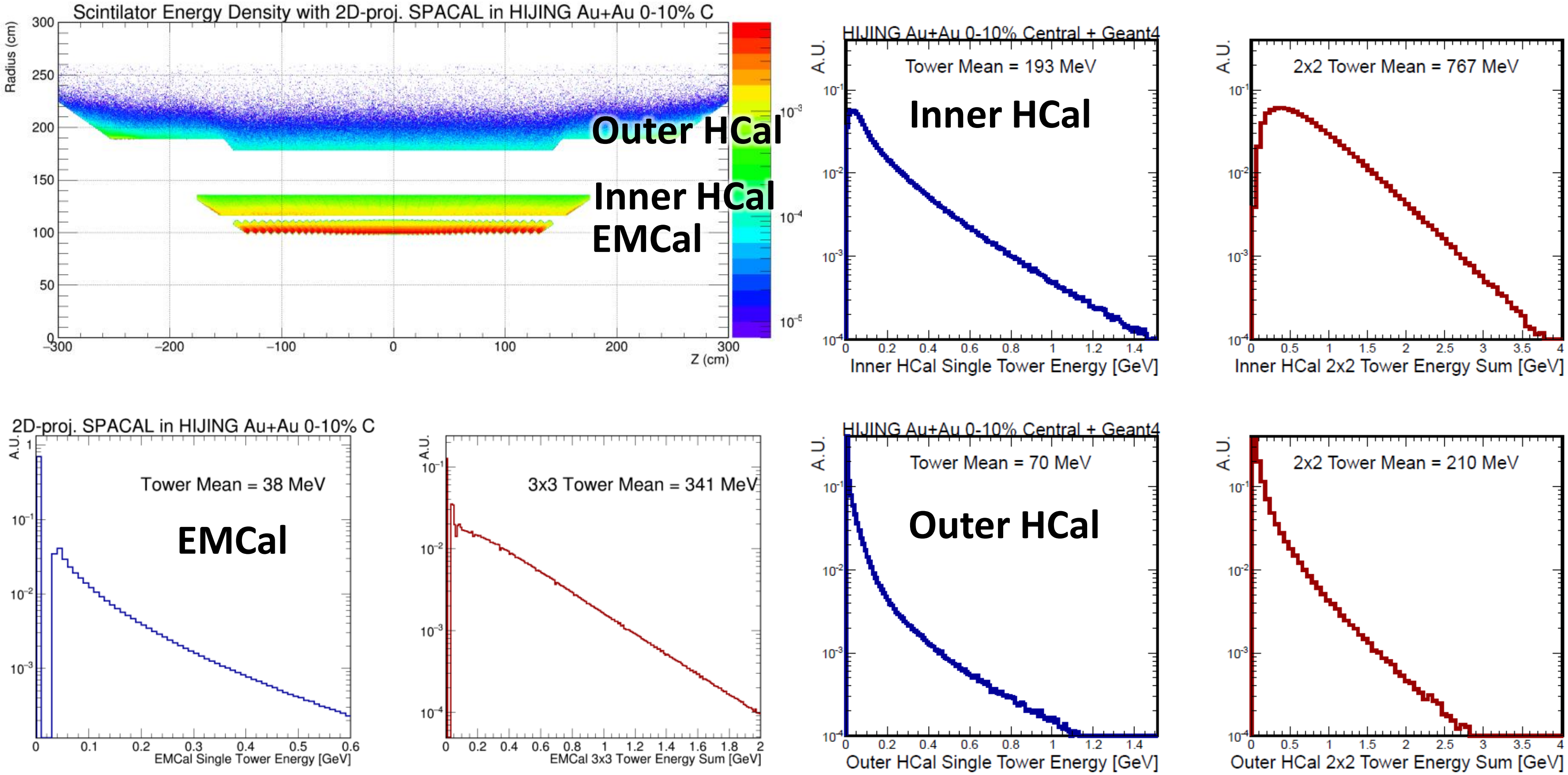
- HCal Simulation tested against Apr 2014 sPHENIX Fermi-lab test beam (HCals alone, v1-design)
- Reasonably reproduced resolution
- New test beam Apr 2016 with full calorimeter system planned (EMCal + Inner Hcal + magnet gap + Outer HCal)





Occupancy in central Au+Au

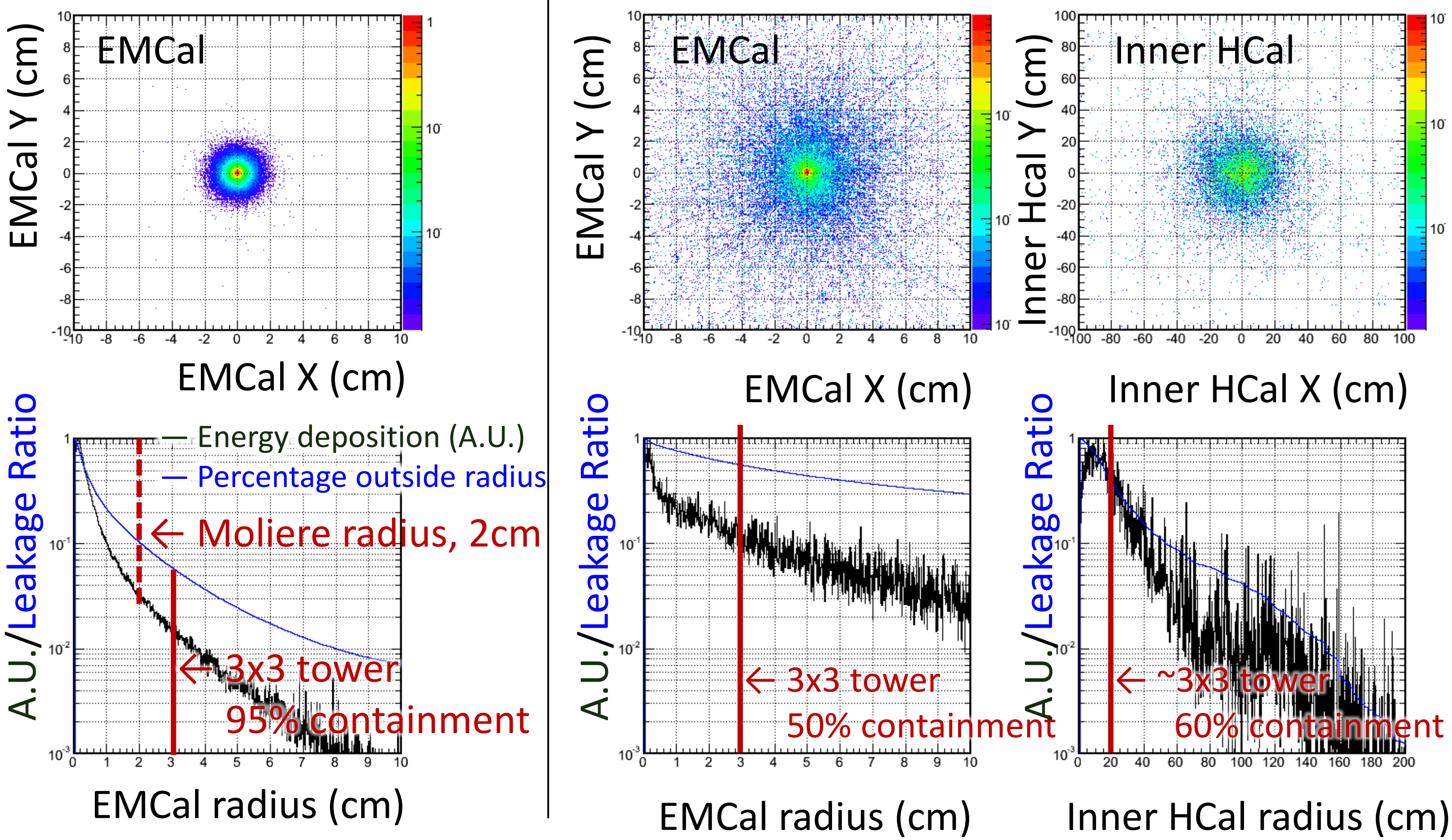
- sPHENIX are designed to handle large background environment of central AuAu collisions
- Such background is simulated with HIJING → full detector in Geant4 → full analysis chain
- Folded into electron ID and jet projections via embedding



Performance : Single EM showers

4 GeV Electrons

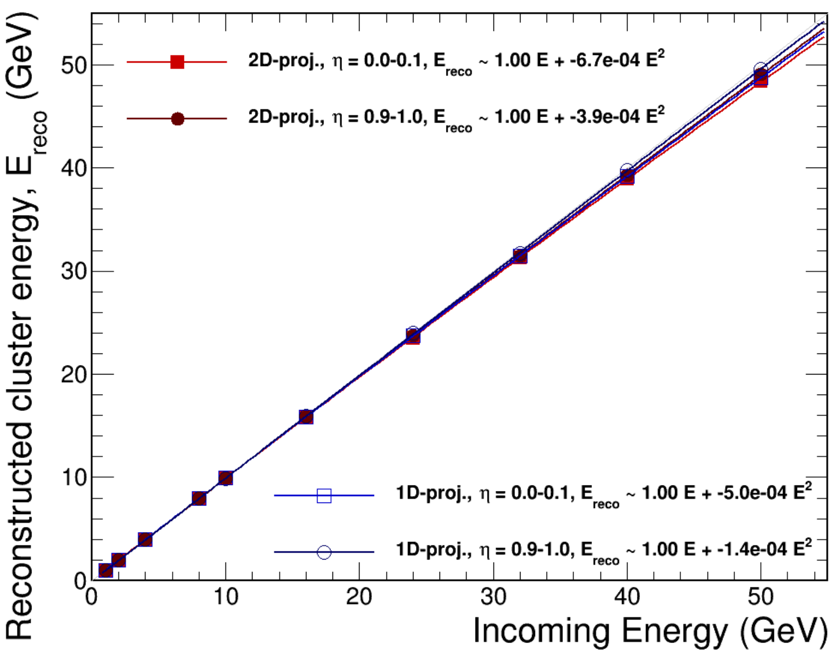
4 GeV Pions, that **passed E/p electron-ID cut**

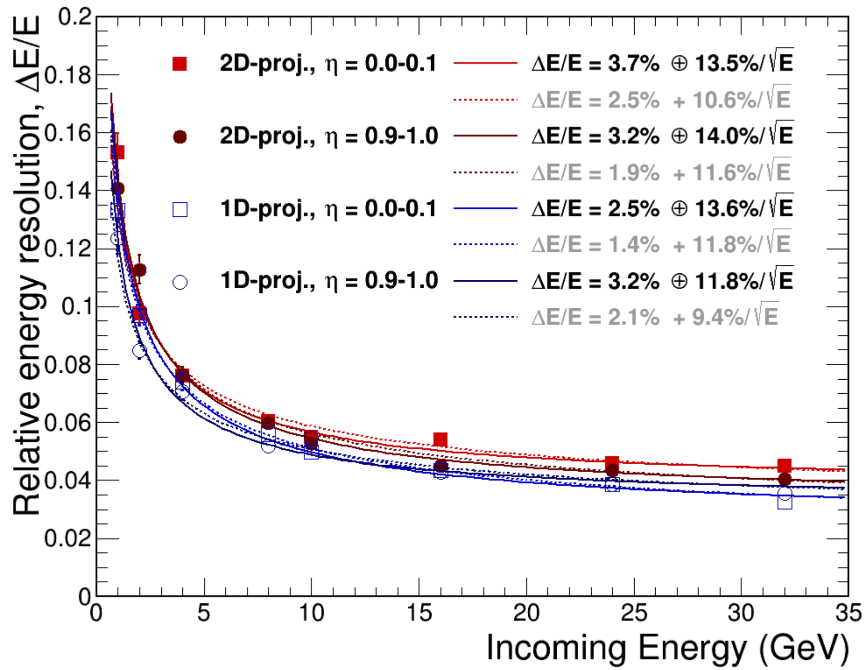


Performance : Single EM showers

- dE/E < 14%/sqrt(E)+4% for photon (fit sPHENIX γ-jet goal)
- dE/E < 12%/sqrt(E) for electrons (fit EIC electron kine. goal)
- Good linearity

sPHENIX full detector single photon simulation





Physics Performance : electron-ID

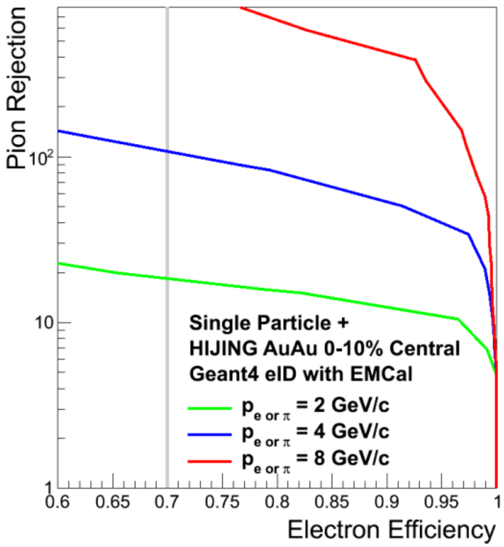
- Critical driving factor for EMCal design: Upsilon electron ID & Triggering
- Baseline electron ID: satisfied scientific goal

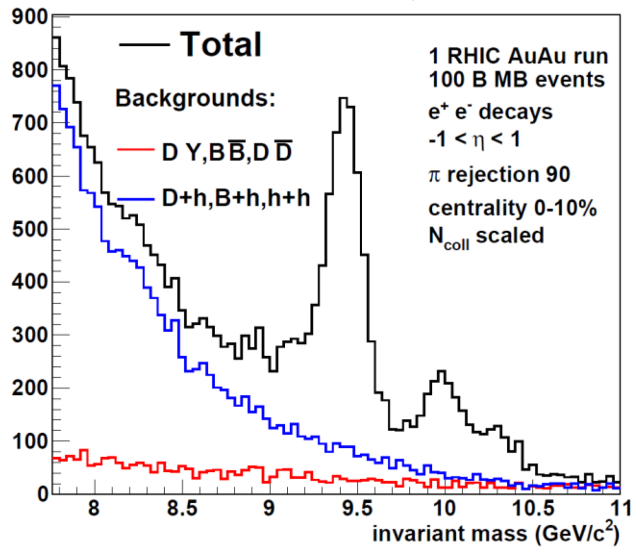
Baseline EMCal performance + Baseline tracker performance → Satisfied the scientific goals

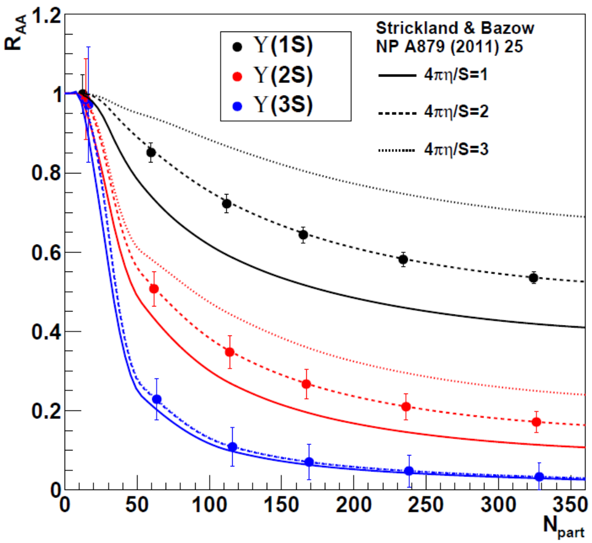
Hadron Rej. ~100:1 @ 4 GeV
(in central AuAu col.)

Δm_{ee} = 100 MeV
Hadron VS Upsilon

Upsilon R_{AA}

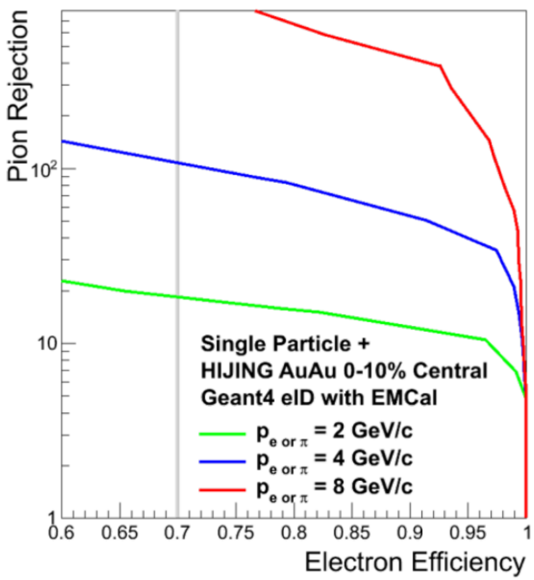


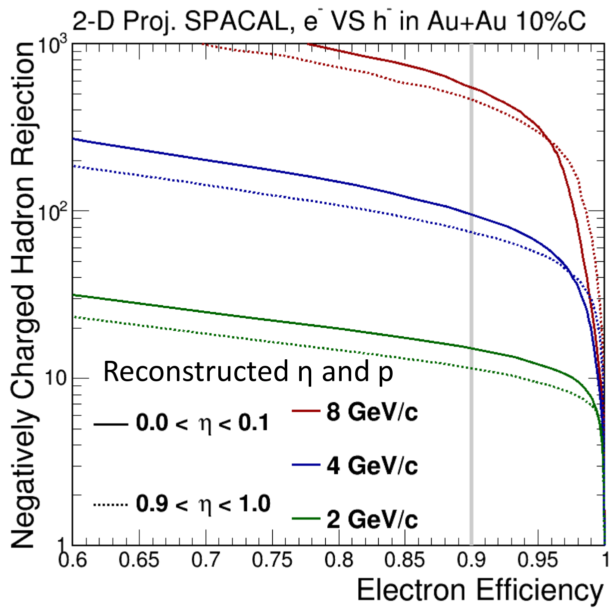


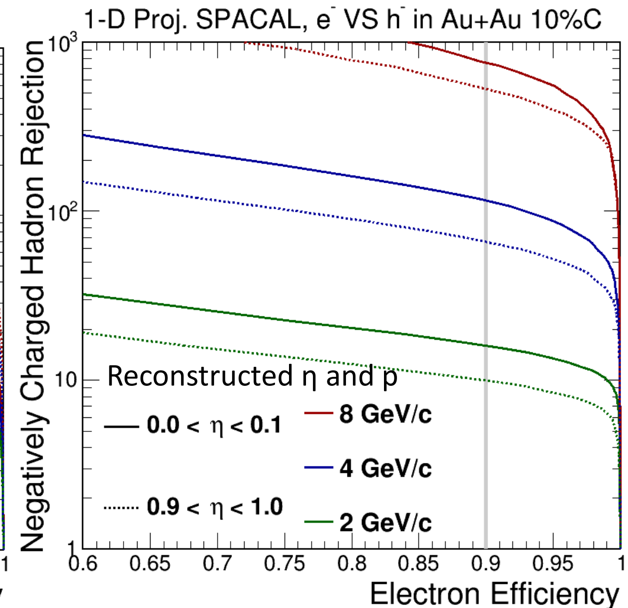


Performance : electron-ID in Au+Au

Updated and more detailed simulation show good safety margin on electron-ID performance on top of the baseline design (as required to reach Upsilon program physics goal)







Baseline performance,
design goals

- Sum all scintillator energy
- 1D SPACAL material with hits grouped into 2D SPACAL towers

2D projective SPACAL

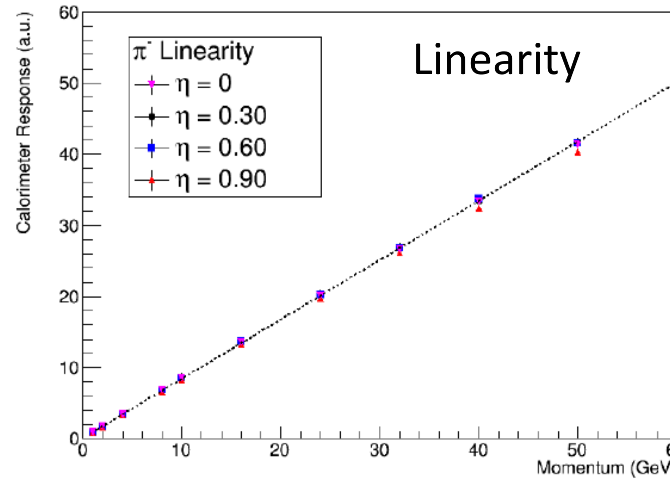
- Updated studies (Preliminary)
- Sum all hadron taking account of hadron ratio
- Full digitization (w/ Birk corrections)
- Full tracking with silicon opt.
- Fully implemented 2D SPACAL (tower/support structure)

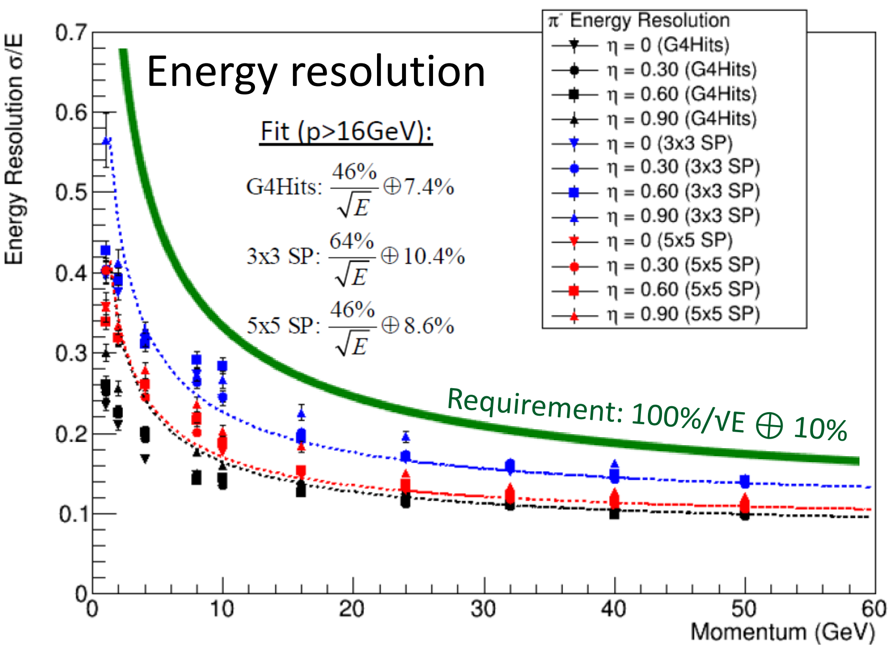
1D projective SPACAL

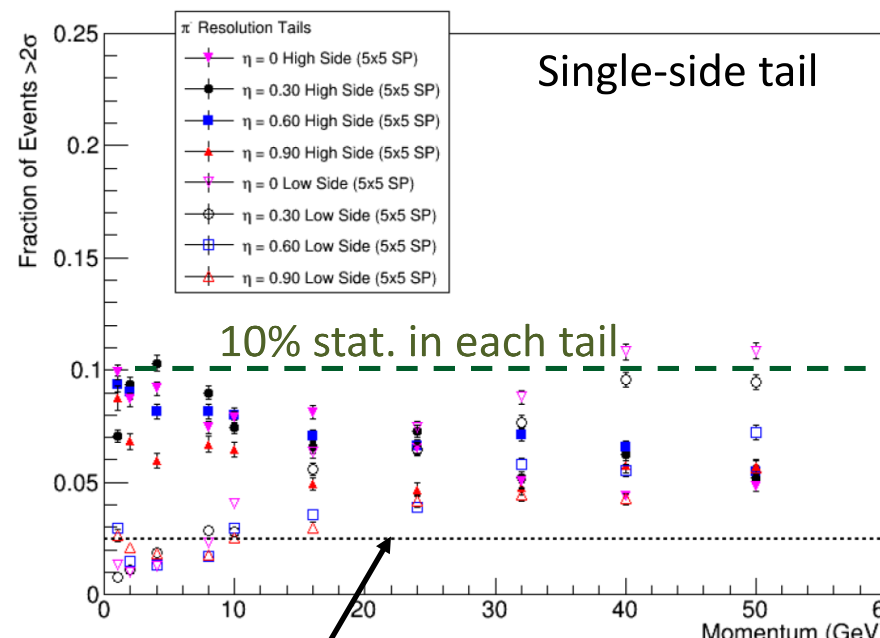
- Updated studies (Preliminary)
- Sum all hadron taking account of hadron ratio
- Full digitization (w/ Birk corrections)
- Full tracking with silicon opt.
- Ideally towering (no-tower boarder, no enclosure structure)

Performance : Single Hadron showers

- Single pion shower studied with clusters of digitized towers (3x3 and 5x5 clusters), which is compared with ideal sum of Geant4 hit in scintillator (label G4Hits)
- Energy resolution satisfied design goal. Tails <= 10%



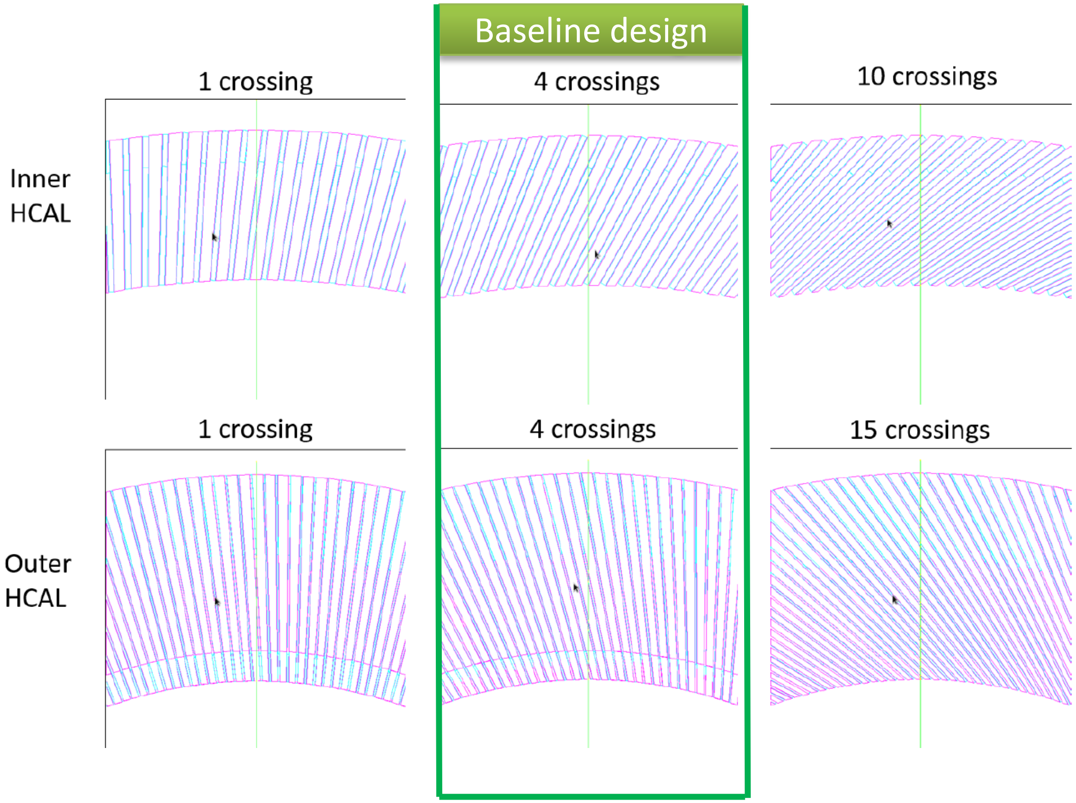


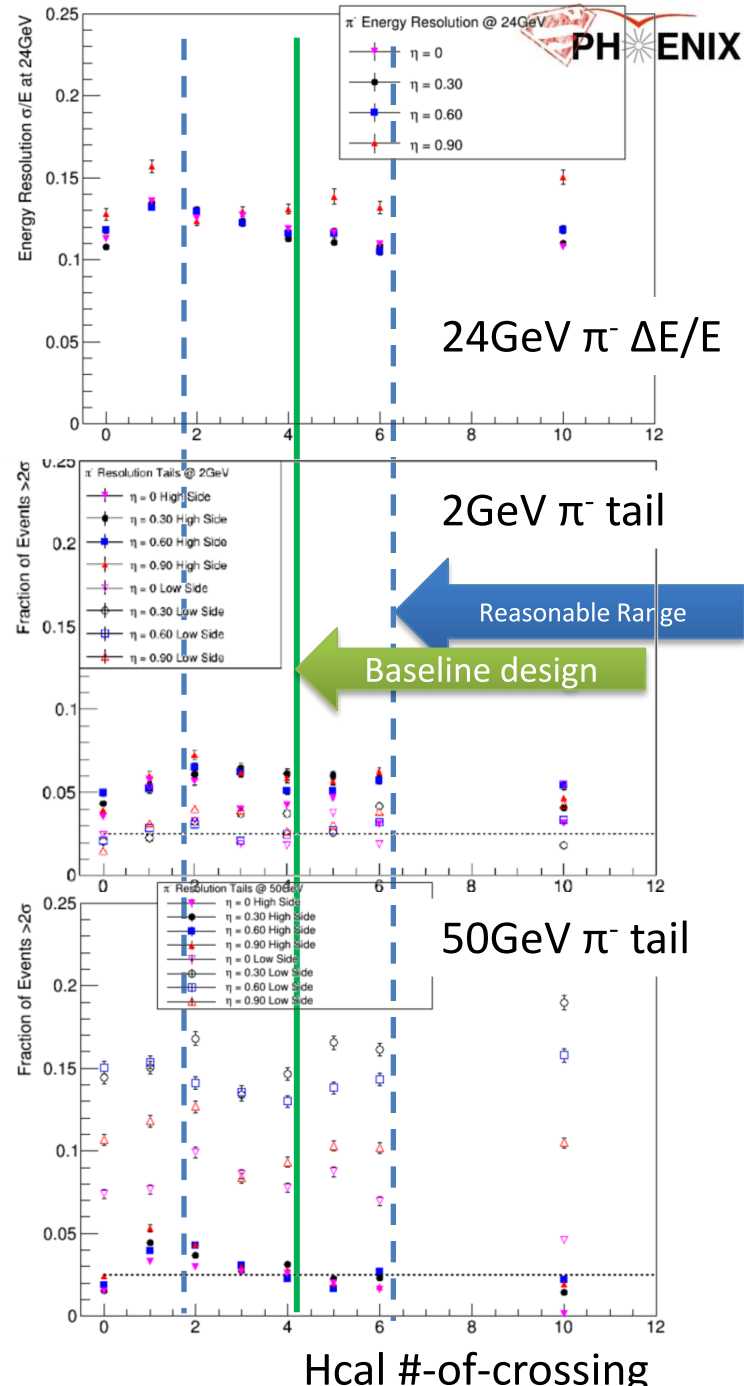


2.5% stat. in tails as expected from Gauss shape

Tilt angle optimization

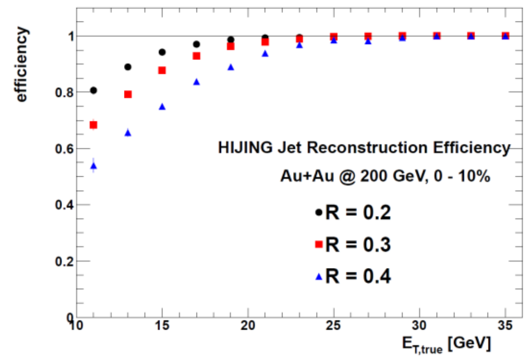
- Performance not a strong function of tilt angle of Hcal iron plates
- Baseline design (4-crossing tilt angle) is a reasonable choice

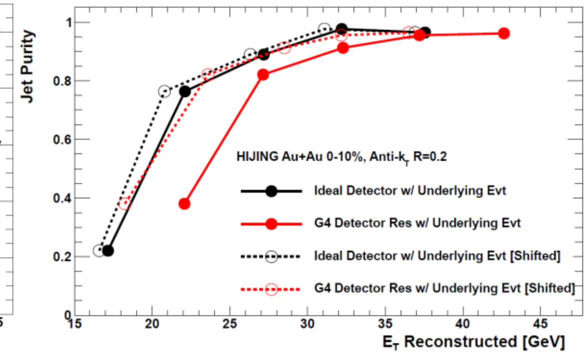


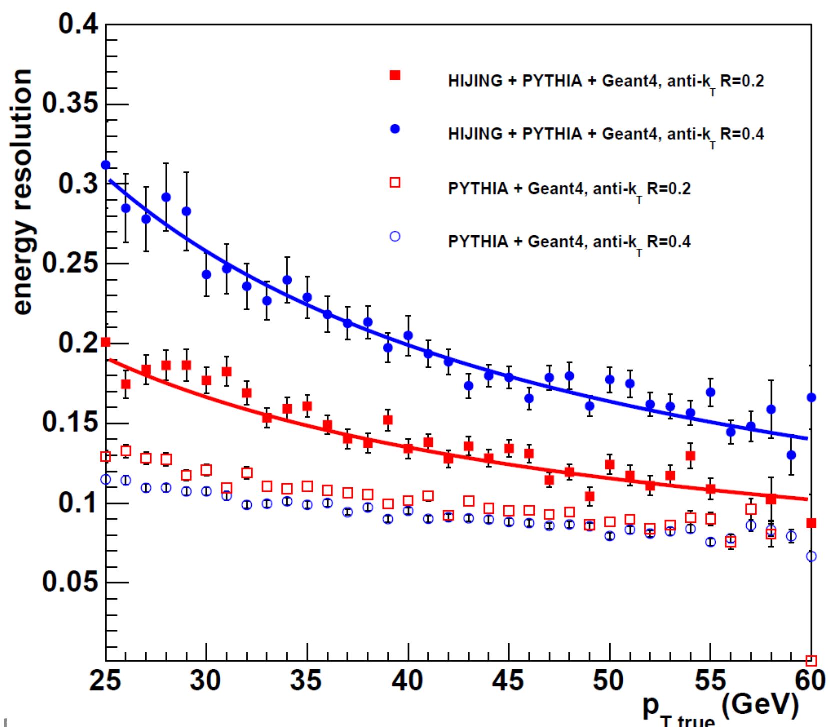


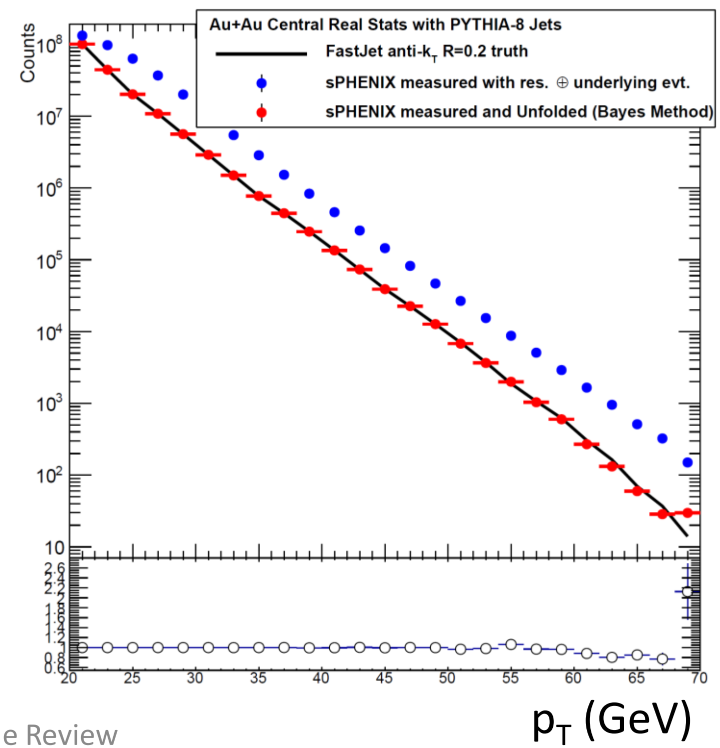
Performance : Jets in central Au+Au

- Algorithm developed based on ATLAS and CMS heavy ion experience
- Good efficiency and purity
- Resolution/tails fit for unfolding jet spectrum
- Need to keep updated as detector design/performance evolves



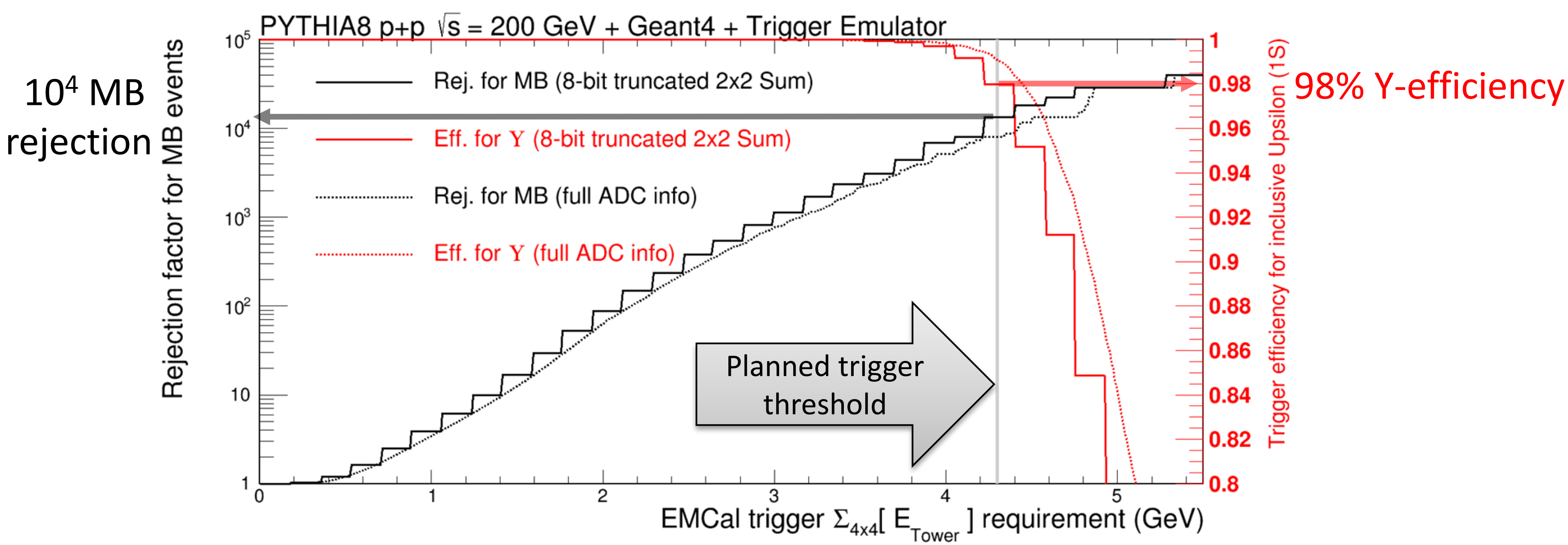






Trigger Performance

- Most challenging is trigger in pp for rare Upsilon signal
- Simulated in trigger emulator with truncated ADC bits
- > 5000:1 rejection with 98% Upsilon efficiency
- <1kHz, easily fit Upsilon in the PHENIX DAQ bandwidth



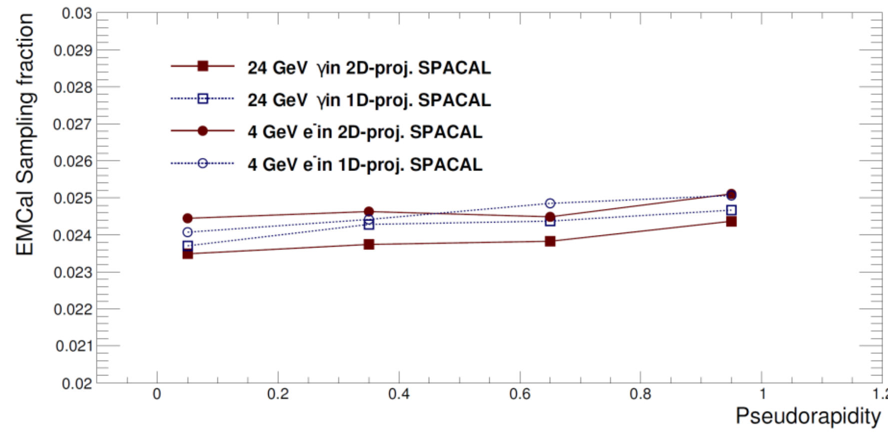
Summary

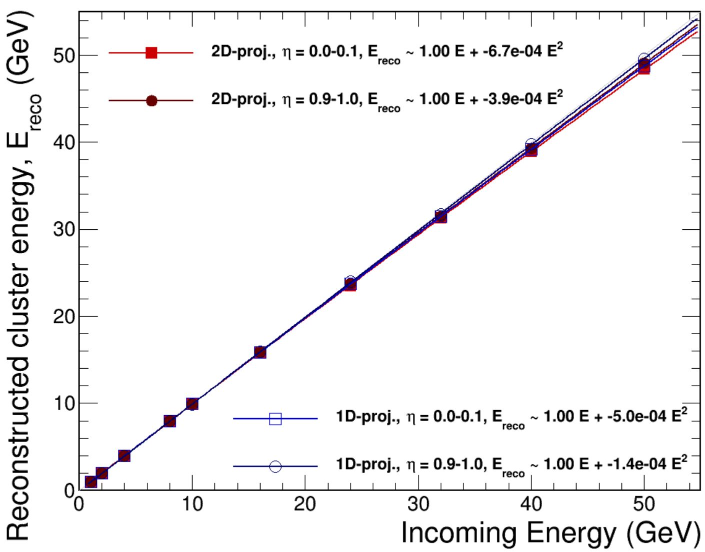
- A detailed model of the sPHENIX calorimeter has been implemented in GEANT4 and used for design and performance studies
- Good agreement with v1 prototype test beam data
  - Simulation of v2 prototype coming in 2016 will guide detector design
- Calorimeter performance achieves the scientific goals
  - Continue work by the collaboration to update the physics performance plots with refined detector design and simulation

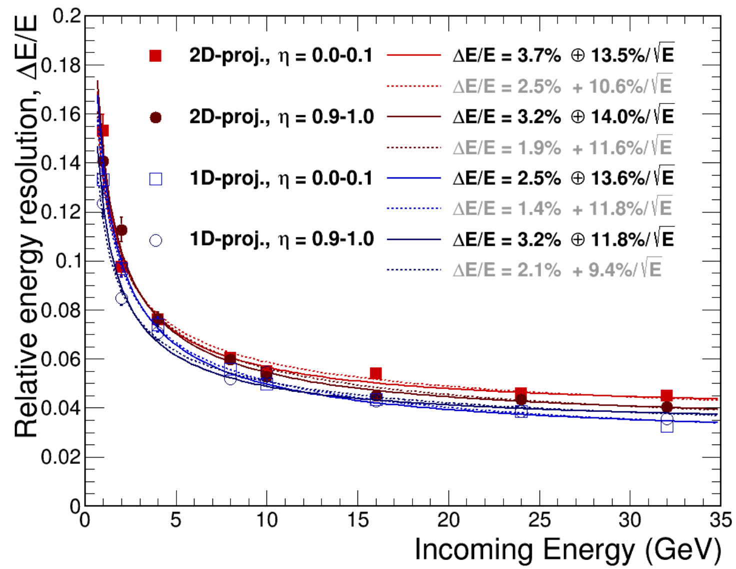
EXTRA INFORMATION

Depth dependency of EMCAL sampling fraction

- Difference between sampling fraction for outer and inner radius is 8% for 2-D projective SPACAL and 4% for 1-D projective version.
- Better presented in energy dependency of sampling fraction and in linearity
- Good linearity observed for both 1-D and 2-D projective designs

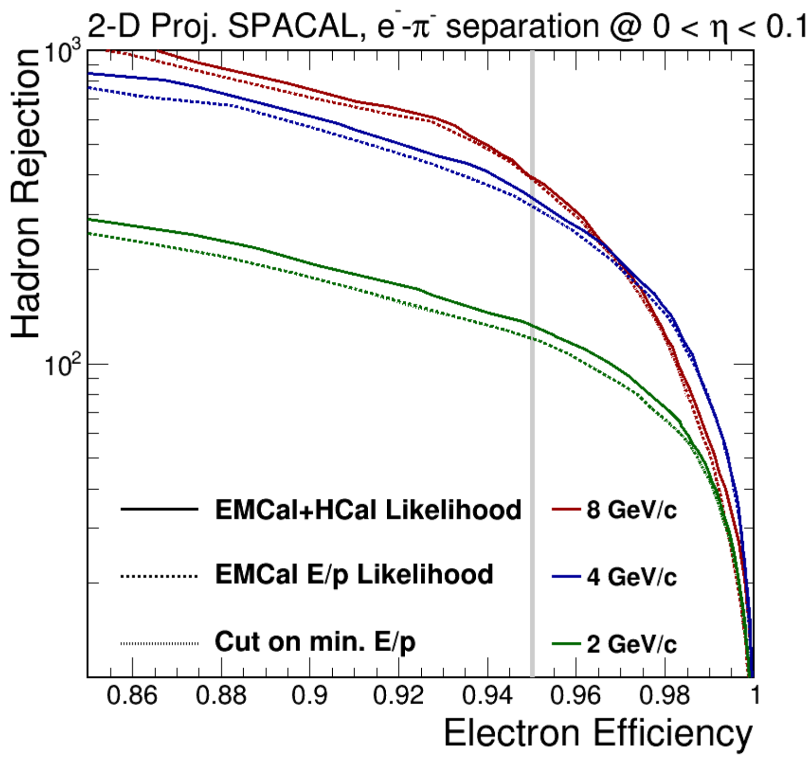


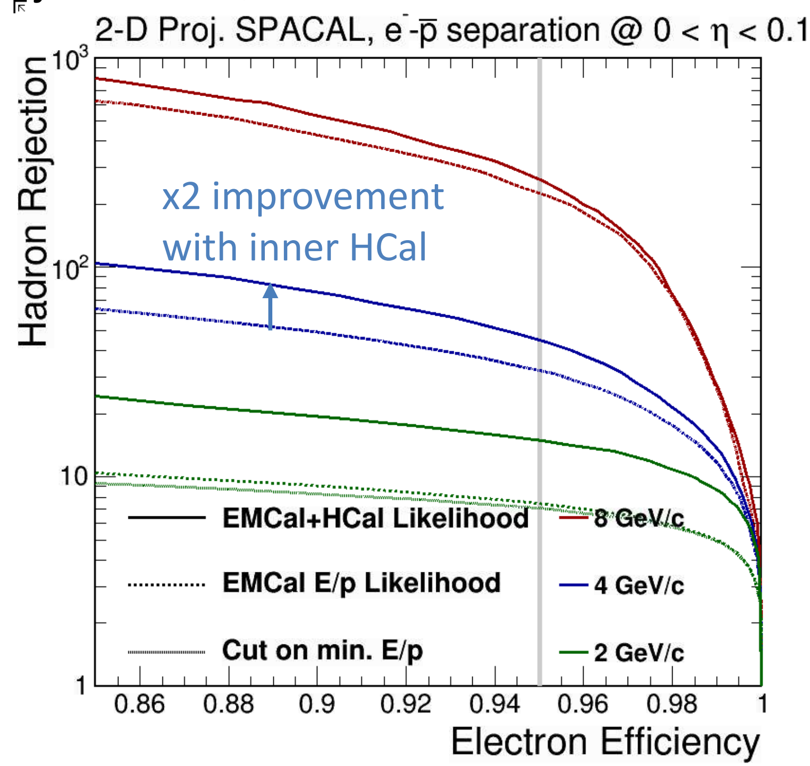




Is inner Hcal useful in e-ID?

Single particle 2/4/8 GeV shower in 2D proj. SPACAL @ eta=0





- Pion Rejection curve (pro1.beta5)
- Full digitization (w/ Birk corrections) Fully implemented 2D SPACAL

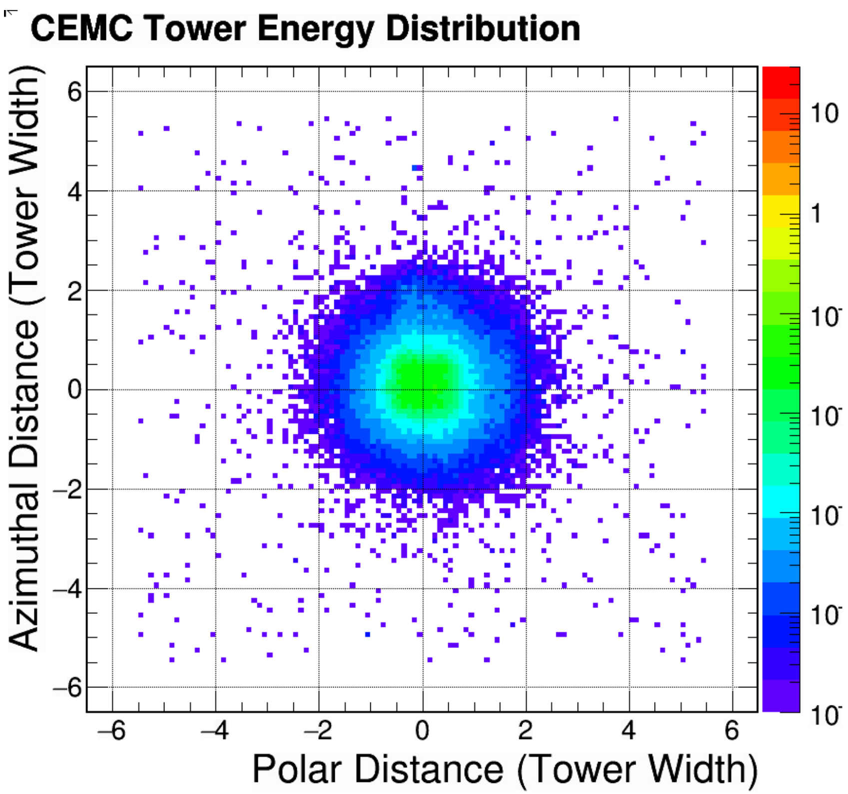
- Anti-proton Rejection curve (pro1.beta5)
- Full digitization (w/ Birk corrections) Fully implemented 2D SPACAL

Cluster in 1D/2D SPACAL

Single e- 8 GeV shower in 1D/2D proj. SPACAL @ eta=0.9-1.0

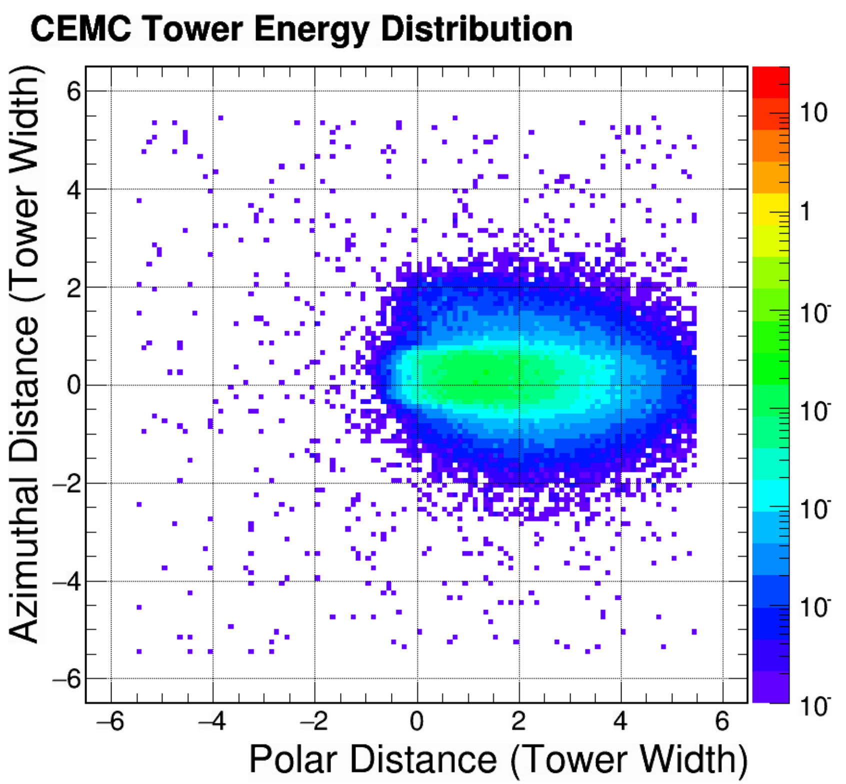
2D projective SPCAL

Average cluster ~8 towers



1D projective SPCAL

Average cluster ~12+ towers



Performance : electron-ID in p+p

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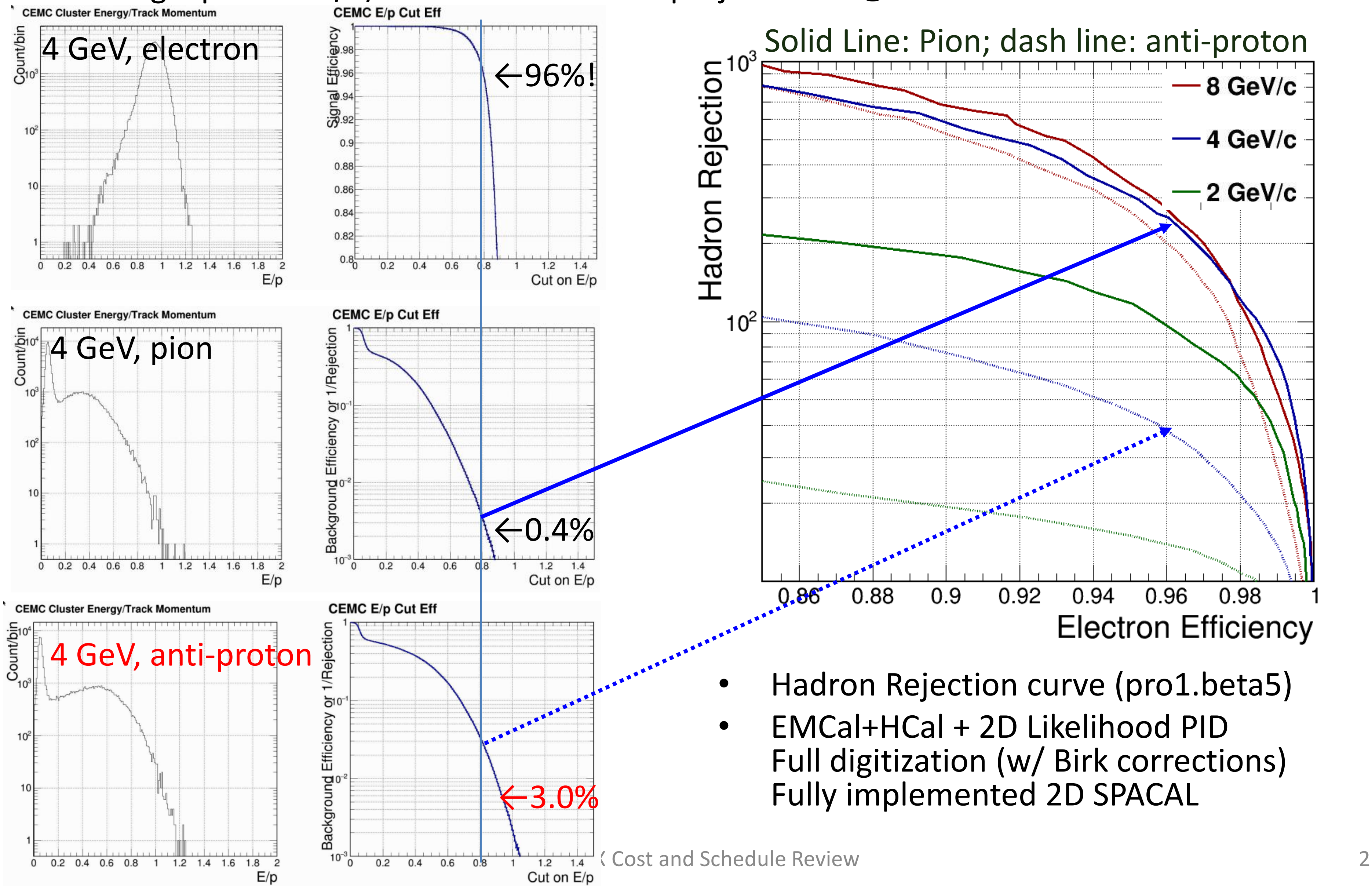
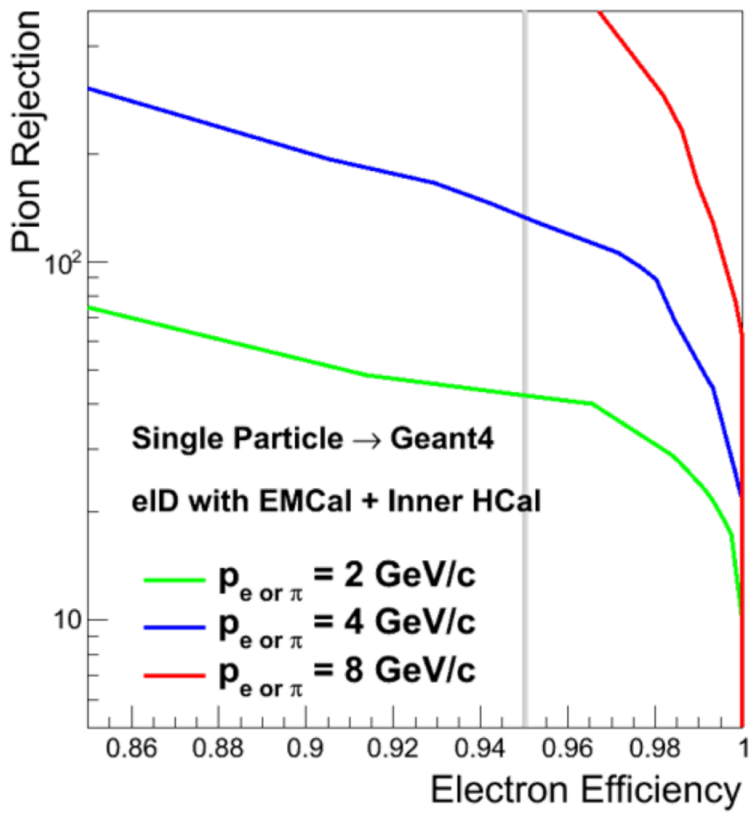
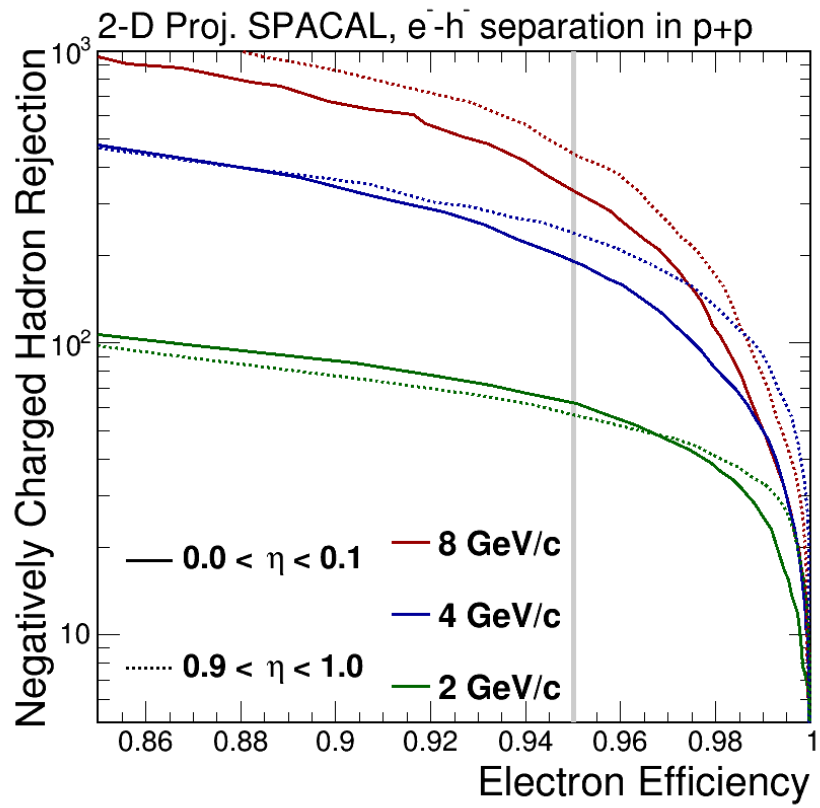


- Hadron Rejection curve (pro1.beta5)
- EMCal+HCal + 2D Likelihood PID
  Full digitization (w/ Birk corrections)
  Fully implemented 2D SPACAL

Performance : electron-ID in p+p

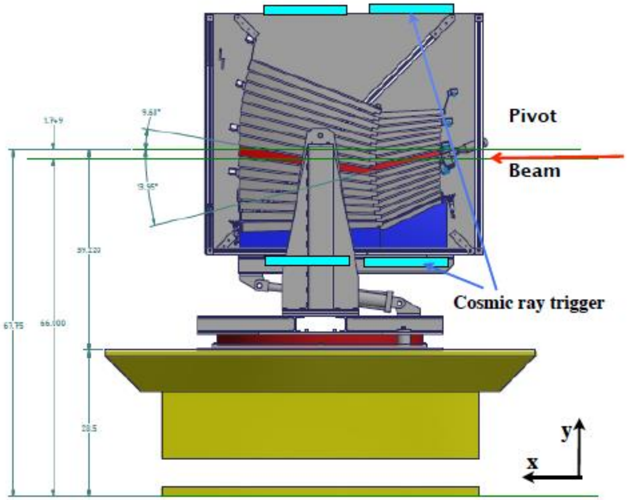


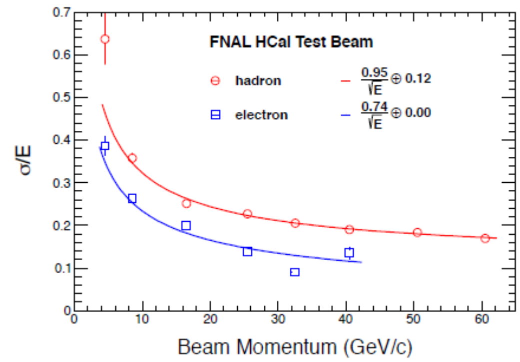


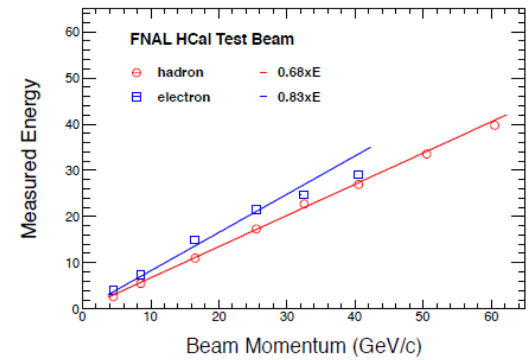
- Baseline performance
- Sum all scintillator energy
  1D SPACAL material cut into 2D SPACAL towers

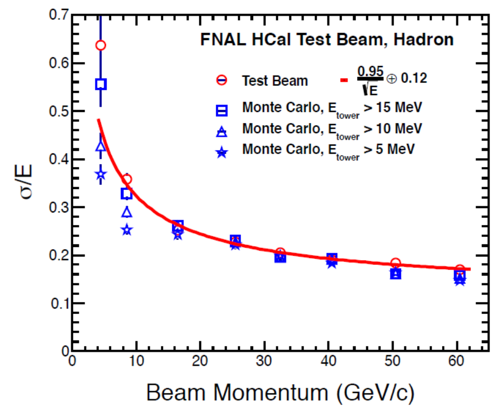
- Updated studies (Preliminary)
- Sum all hadron taking account of hadron ratio
  Full digitization (w/ Birk corrections)
  Fully implemented 2D SPACAL

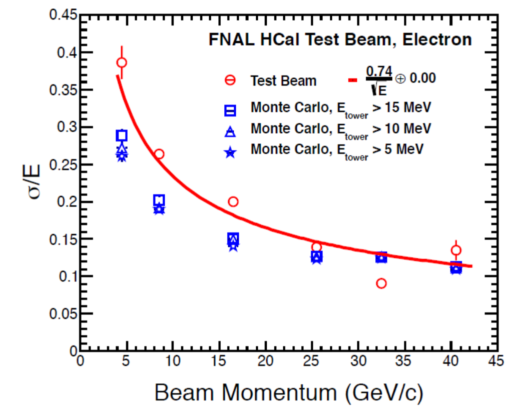
Hcal Test beam 2014 FNAL

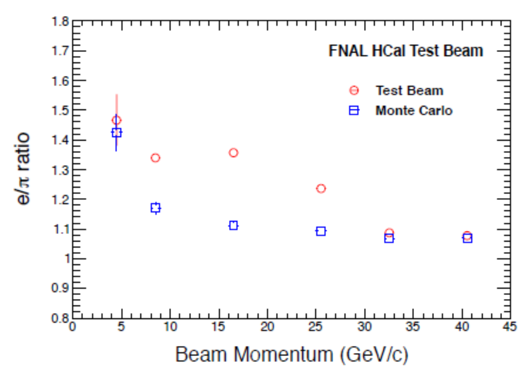




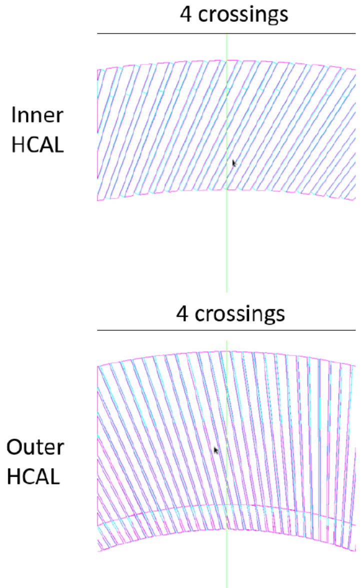


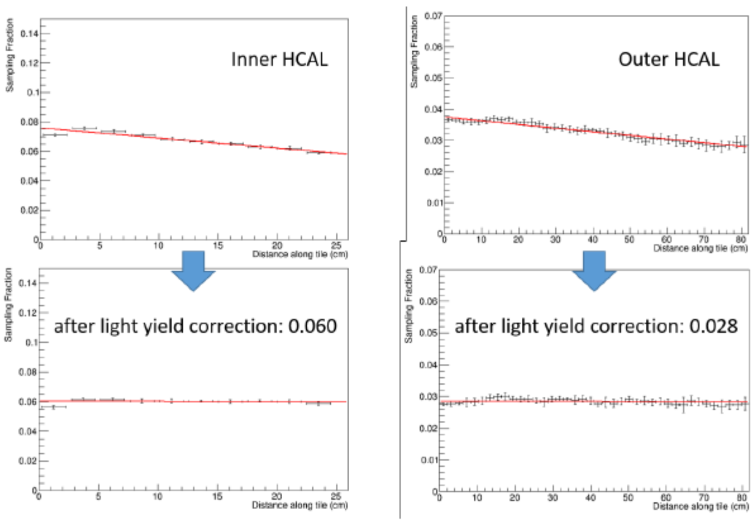




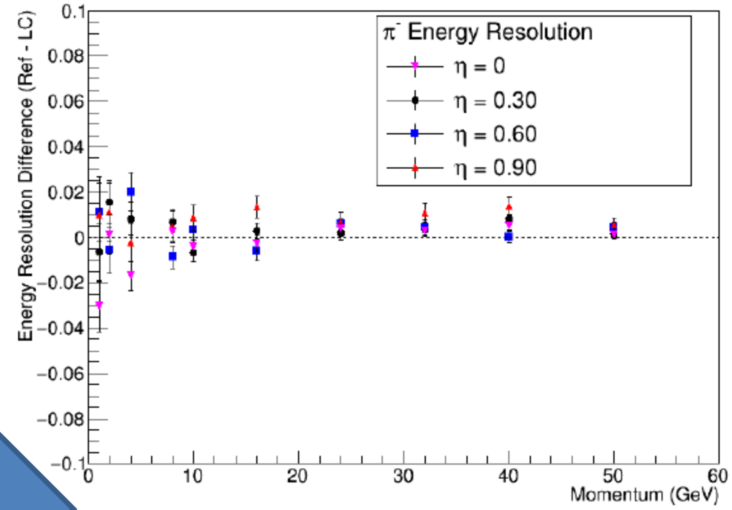


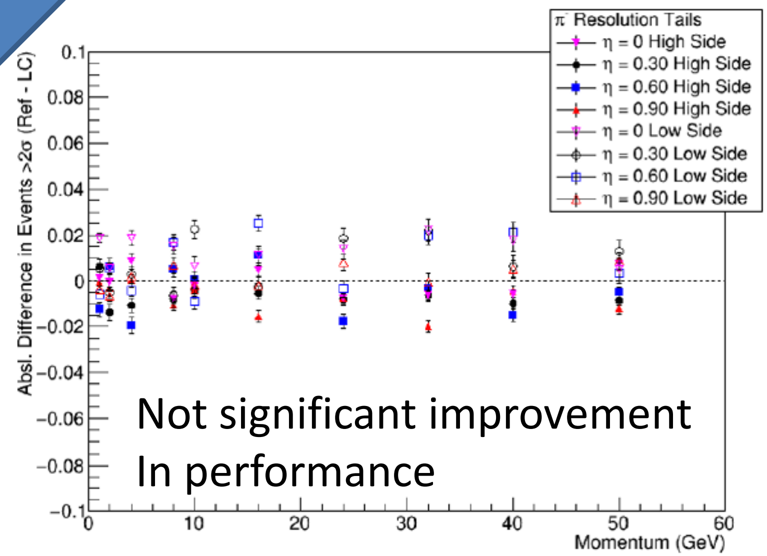
Hcal tile details





Correct for depth dep. Sampling fraction





Not significant improvement
In performance